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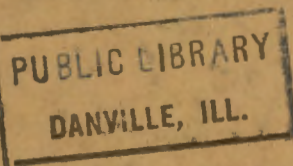
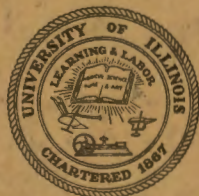
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SAVE FUEL FOR VICTORY

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THE Engineering Experiment Station was established by act of the Board of Trustees of the University of Illinois on December 8, 1903. It is the purpose of the Station to conduct investigations and make studies of importance to the engineering, manufacturing, railway, mining, and other industrial interests of the State.

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UNIVERSITY OF ILLINOIS  
ENGINEERING EXPERIMENT STATION  
CIRCULAR SERIES No. 47

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SAVE FUEL FOR VICTORY

A series of non-technical articles about insulation, heating-plant efficiency, and related subjects, originally presented as talks over the University of Illinois Radio Station WILL. All the speakers are members of the staff of the Department of Mechanical Engineering in the College of Engineering and the Engineering Experiment Station of the University of Illinois.

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## I. SAVE FUEL BY REDUCING SMOKE

JULIAN R. FELLOWS\*

Unnecessary smoke caused by improper firing of soft coal—technically known as bituminous coal—wastes many millions of dollars worth of the coal every year, besides causing damage to buildings, to vegetation, and to health amounting to many additional millions of dollars. It is the patriotic duty of every citizen who burns soft coal in hand-fired furnaces, boilers, stoves, and water heaters to fire it in a way that will reduce waste to a minimum.

A special study of the smoke problem has been completed recently in the Mechanical Engineering Laboratory at the University of Illinois. The object of this study was to determine the method of firing which produces the best results from the standpoint of heating comfort and smoke reduction.

While the study disclosed the fact that there is no known method of hand-firing soft coal by which smoke can be entirely eliminated, it did prove that proper methods may eliminate as much as three-fourths of the smoke. The tests showed that heavy smoke resulted from improper methods of adding fresh fuel in a furnace, boiler, or stove. If the best results in fuel saving through smoke reduction are to be obtained when using soft coal in a hand-fired home heating plant, the firing—that is, adding of fresh fuel—must be done properly.

Summarizing,† the most important rules for obtaining the best possible results from a hand-fired heating plant burning soft coal are:

- (1) Have your longest poker converted to an oblique-angle shape so that you can reach any part of the grate area with the point.
- (2) Use the oblique-angled poker to move all hot coals from the area of the grate which is to receive the charge of fresh coal. Do not fire any fresh coal until the fuel bed has burned away sufficiently to permit you to clear at least one-fourth of the grate area.
- (3) Use the oblique-angled poker to break up all clinkers and work all fine ash through the grate area which is to receive the fresh coal.
- (4) In placing a charge of fresh coal at one side of the fire pot, put the coarser pieces on the bottom and the finer particles on the top of the charge and next to the wall of the fire pot.
- (5) Avoid covering the hot coals with the fresh coal insofar as it is possible to do so.

\*Assistant Professor of Mechanical Engineering, University of Illinois.

†Professor Fellows discussed in detail the proper hand-firing of soft coal in home heating plants—furnaces, boilers, or stoves. The details are omitted here because they are presented fully in Engineering Experiment Station Circular No. 46, "Hand-Firing of Bituminous Coal in the Home," copies of which are free on request.

(6) After the fresh coal has been placed, use the oblique-angled poker to break up the hot coke from the previous charge so that it will burn uniformly and not form a hole in the center of the fuel bed.

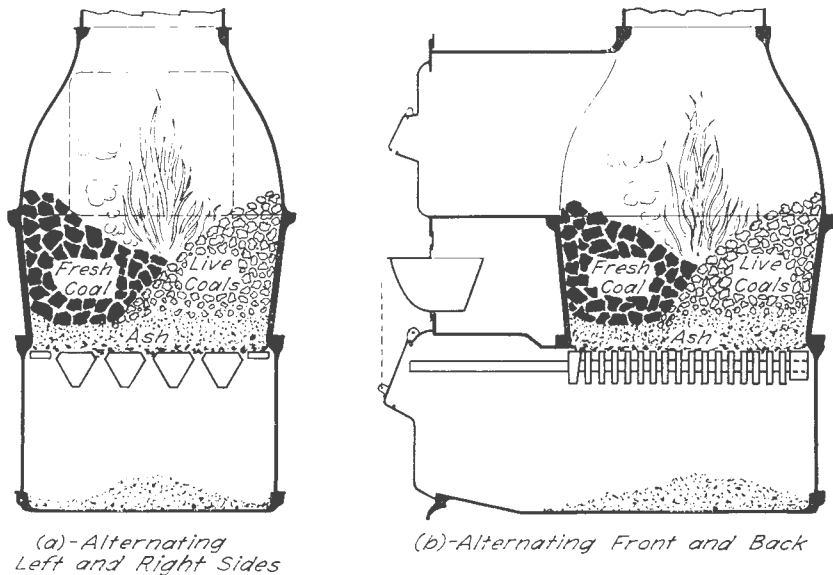


FIG. 1. SIDE-BANK METHOD OF FIRING

This method is a great improvement over the ordinary spreading method.

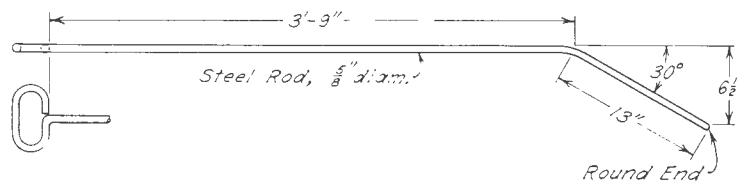


FIG. 2. OBLIQUE-ANGLED POKER

This type of poker is essential for best results in hand firing.

(7) Make certain that the hot coals have ignited the gas before you consider the task is complete. Use tightly crumpled papers if necessary to start the gas flame.

Do not become discouraged if your first attempts to fire your heating plant properly fail to achieve the results you had hoped for. Proper firing of soft coal is an art which can be mastered by any intelligent person, but, as with any art, persistent effort is required if you

are to become proficient. If you do not succeed at first, try again, and when you have learned to fire the coal properly your efforts will be well repaid in reduced smoke and better results from your heating plant.

In reducing smoke you will be making your community more healthful, you will be saving your own money, and you will be saving fuel to help America to Victory.

## II. KNOW YOUR FUEL

JULIAN R. FELLOWS\*

Before our country became involved in this World War, the modern householder, living in the more progressive areas, could freely choose the fuel for heating his home from a long list of competing types.

Present day fuels for home heating can be listed in the order of their convenience as follows:

- (1) Natural gas or coke oven gas.
- (2) Oil; this fuel is placed after gas in the order of convenience only because it is necessary for the householder to watch the fuel storage tank and have it refilled before it becomes empty.
- (3) Either anthracite coal, commonly known as hard coal, or bituminous coal, commonly known as soft coal, when burned in mechanical stokers. Coal when burned in automatic equipment is inferior to gas and oil from the standpoint of convenience only because it is necessary to refill the hopper when it becomes empty and to remove the ash or clinkers.
- (4) Hard coal is the most convenient fuel for use in the hand-fired heater because it does not raise dust when handled, it does not require special firing methods, and it works well in heaters equipped with a magazine for feeding the coal into the fire.
- (5) Coke; this is made in coke ovens by heating a good grade of soft coal to drive out the gas, and is listed after hard coal because it is more inclined to raise dust when handled and is less dense, thereby requiring a greater storage space. The low density also limits the weight that can be fired at one time, and, as a result, the fire requires more frequent attention.
- (6) Semi-bituminous coal, generally known as smokeless soft coal, is an excellent fuel in hand-fired heating plants, but it is listed after hard coal and coke because it is a coking coal which in burning is first formed into a mass of hard coke that must be broken up with a poker before it will produce a hot fire.
- (7) Ordinary soft coal, when fired by hand, must be listed after all the other fuels mentioned, from the standpoint of convenience.

Careless methods of firing result in the production of huge volumes of black smoke, the collection of soot in the various parts of the heating plant, occasional explosions of gas in the combustion chamber, and generally unsatisfactory performance. However, tests and experience have shown that when the proper methods are employed in hand-firing

soft coal smoke is produced in very small amount, soot accumulations are not sufficient to cause trouble, explosions are positively eliminated, and generally satisfactory results are achieved. Convenience is a factor which cannot be considered in wartime and, if you live in Illinois or any other area where soft coal is abundant and you have a heating plant in which soft coal can be burned, it may be your duty to burn it and to learn to fire it properly. If you are burning oil, it may be your duty as a patriotic citizen to change to soft coal, providing the design of your heating plant will permit the installation of grates for burning it.

There are a number of other fuels which are used for home heating in certain areas. Probably the most important of these is wood, which was at one time the principal domestic fuel, and is still used extensively in many wooded areas. In industrial districts where wood is scarce, it is used only as kindling, in open fireplaces, and for camp fires. Sub-bituminous coal, lignite and dried peat are used in some parts of the country where they are found in abundance, but the fuels previously listed are the only ones used for heating in Illinois and nearby areas.

The price of fuel for domestic heating is determined largely by the convenience afforded by its use rather than by its heating value. Since gas is sold by the cubic foot or therm, oil by the gallon, and coal by the ton, the cost of the different fuels cannot be compared directly from the commercial price quotations. If the convenience factor is eliminated, the householder is concerned only with the heat that will be liberated when the different fuels are burned in his heater. The unit of heat used in this country is the British thermal unit usually abbreviated B.t.u. This is defined by the American Society of Mechanical Engineers as the average amount of heat required to raise the temperature of a pound of water through one degree Fahrenheit between the conditions of freezing and boiling at standard atmospheric pressure. When the housewife draws a quart of water from the faucet at 60 degrees and heats it to the boiling point for tea, she has utilized approximately 319 B.t.u. of heat.

The approximate heating values of the common domestic fuels in B.t.u. per sale unit are as follows:

Natural gas—1000 B.t.u. per cu. ft. or 100 000 B.t.u. per therm.

In some localities, natural gas is sold by the therm, which is 100 cu. ft.

Coke oven gas—565 B.t.u. per cu. ft.

Oil—140 000 B.t.u. per gallon

\*Assistant Professor of Mechanical Engineering, University of Illinois.



Hard coal—26 000 000 B.t.u. per ton

Coke—26 000 000 B.t.u. per ton

Smokeless soft coal—29 000 000 B.t.u. per ton, and soft coal from 20 000 000 to 30 000 000 B.t.u. per ton, depending on the type that is used.

In comparing the cost of the heat which is stored in the different fuels, the figures used in the comparison will be more comprehensible if the comparison is made on the basis of the cost of one million B.t.u. The cost of one million B.t.u. of heat in the fuel may be easily calculated from the price per commercial sale unit by multiplying the price per sale unit in cents by one million, then dividing the product by the heating value of one sale unit in B.t.u. For example, the heat in natural gas purchased at the rate of six cents per therm costs six times one million divided by one hundred thousand, or sixty cents per million B.t.u. and, by a similar calculation, the heat in oil purchased at a price of 7.4 cents per gallon costs 7.4 times one million divided by one hundred and forty thousand, or 52.9 cents per million B.t.u., likewise the heat in hard coal purchased at a price of fifteen dollars per ton costs fifteen hundred times one million divided by 26 million, or 57.7 cents per million B.t.u.

#### COMPARATIVE FUEL COSTS IN RELATION TO HEATING VALUES

Based on approximate heating values and price quotations at  
Urbana, Illinois, October 6, 1942

Fuel	Millions of B.t.u. Per Sale Unit	Typical Cost Per Unit, dollars	Cost per Million B.t.u. in the Fuel, cents
Local soft coal.....	20	\$4.50	22.5
Medium grade of soft coal.....	24	7.50	31.4
Highest grade of soft coal.....	29	9.30	32.1
Smokeless coal.....	29	10.00	34.4
Low temperature coke from Illinois coal.....	23	9.00	39.2
High grade coke from Eastern coals.....	28	14.30	51.1
Oil.....	0.14	.074	52.9
Hard coal.....	26	15.00	57.7
Gas.....	0.10	.06	60.0

The price charged for the different fuels varies in different communities, and there is considerable variation in the heating value of some of them, but the following tabulation of the approximate cost of heat stored in the different types will give some basis for their comparison if you live in Illinois or nearby regions:

One million B.t.u. in ordinary soft coal costs from 20 to 30 cents, in smokeless soft coal around 35 cents, in coke about 40 cents, in either hard coal or oil approximately 55 cents, and in gas about 60 cents.

From the foregoing comparison, it can be seen that one million B.t.u. stored in gas, oil, or hard coal costs nearly three times as much as one million B.t.u. stored in soft coal from a mine close to your home. The higher combustion efficiency of the gas burner or the oil burner may partly compensate for the higher cost of the heat in the fuel, but, in general, it may be said that soft coal will provide heat a lower cost than any competitive fuel.

Many homes have been insulated and equipped with storm doors and storm windows which reduce the heat losses to such an extent that it is possible to heat with oil or gas at a cost no higher than when heating with soft coal before the improvements were made. However, the cost of heating would have been greatly reduced by the improvements in the structure if the householder had continued to use soft coal as fuel.

Many householders have burned soft coal for years without giving any thought to improving their homes with insulation, storm windows, storm doors, weather stripping, etc. Wise salesmen of oil and gas heating installations have usually insisted on those improvements being made when installing their equipment. The fact that you are burning soft coal is not a reason for neglecting to improve the structure of your house. It is possible for you to increase the comfort in your home immeasurably by the use of heat-saving devices and the application of proper firing methods even though you continue to hand-fire soft coal in your heating plant.

In fuel for home heating you pay for convenience when you use the more expensive types, such as gas or oil. In normal times it is your privilege to spend your income in whatever way you may choose, and if you choose to pay more for a fuel which requires less of your time for attending the heating plant, that is of no concern to any one but yourself. However, our country is now at war. Our war industries, which are attempting to keep our armed forces supplied with the tools they require for victory, may need the fuel you prefer. The shipment of vital war materials may require the shipping capacity that would normally be used to bring your favorite fuel from distant wells or mines. In other words, it may be your patriotic duty to change your fuel to one which can be supplied to you with less interference with our country's war effort. If you live in a community in Illinois or a nearby State you can cooperate with your government by burning some type of soft coal from the Midwestern area, providing, of course, that your heating plant may be equipped to burn it.

If solid fuel of any type has ever been burned in your heating

plant, it can be put in shape to burn soft coal by your local furnace dealer, and you can achieve heating comfort and reduce all of the disagreeable features of hand-fired soft coal to a minimum by applying the proper methods of firing.

If you have a furnace especially designed for the burning of oil or gas, it will be impossible for you to change the fuel to coal. In that case, the only practicable way for you to cooperate with the war effort is for you to reduce the consumption of fuel in your home to a minimum by employing every known method of reducing heat losses.

If you live in a soft coal region, burn soft coal in your home heating plant if it is possible to do so, keep your bin filled, as there may be times when it will be difficult or impossible for you to obtain fresh supplies, and learn to use the firing technique which will give the best possible results.

### III. INSULATION SAVES FUEL

ALONZO P. KRATZ\*

The problem of economical heating may be divided into two parts, first, the effective production and utilization of heat, and, second, the effective conservation of the heat produced. While these two parts of the problem are of equal importance, most of the emphasis has been placed on the factors affecting the choice of equipment for efficient production and utilization of heat; and, until recent years, the use of insulation as a means of effective conservation of heat through the reduction of the heat loss from the building as a whole has not received the attention that it merits. At the present time the necessity for saving all fuels, particularly gas and oil, has made imperative better practices in conserving heat in the home, and for this purpose numerous forms of heat insulation materials are readily available.

The necessity for the use of effective heat insulation materials in cold storage rooms where the room temperature must be maintained considerably lower than that of the outdoor air, has been realized by refrigerating engineers for a great many years; and the principles underlying their use have been well established. These principles are not fundamentally different in the case of heating, where the room temperature to be maintained is higher than that of the outdoor air. However, the various conflicting claims regarding the available materials have resulted in considerable confusion on the subject, and created an atmosphere of apparent mystery where no mystery actually exists.

If a building with the inside air and contents at 70 deg. F. is surrounded by outdoor air at less than 70 deg., it is obvious that there will be a continual loss of heat through the outside walls of the structure as long as the temperature difference is maintained. It is also evident, that, if the indoor temperature is to be maintained, the heating system must supply the heat just as rapidly as it is lost from the building. Further consideration, therefore, indicates that no matter how efficient the heating system is, if the building is poorly constructed and leaks heat rapidly, a large quantity of heat must be generated, and the heating cost will be high as compared with that for a building for which the heat leakage is less.

Heat escapes from the building in two ways. Wind blowing on the windward side forces cold air into the cracks around the doors and windows, and at the same time forces a corresponding weight of warm

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air out of the cracks on the other side. This warm air has been heated at the expense of fuel used in the heating plant, and thus represents a preventable loss in fuel escaping through loose windows and doors. The remedy is to caulk all cracks in the window frames, and to use either weatherstripping or tightly-fitting storm sash on all windows. Tightly-fitting storm sash has the additional advantage of saving about one-half of the heat that would normally escape through the glass, as well as practically all of that resulting from air leakage. Tests at the Warm-Air Heating Research Residence at the University of Illinois have proved that the fuel bill may be reduced about twenty per cent by using storm doors and storm sash at all windows.

The second way in which heat escapes is by conduction through the materials forming the walls, floors, and ceilings of the rooms. The amount of heat conducted depends on the nature and thickness of the materials. The denser materials are, as a rule, the better conductors, and hence the poorer insulators. All metals are very poor insulators: wood is a better insulator than stone, brick, or concrete; and a dead air space, or one in which no air movement takes place, is about the best heat insulator known. For any given material, increasing the thickness reduces the amount of heat conducted in a unit of time. Hence, heat may be saved either by using the same thickness of a better insulator, or by increasing the thickness of a poorer one. When fuels were inexpensive and plentiful, wood, brick, concrete, and stone were considered sufficient for the purpose of insulation. At the present time, however, it has become advisable to use additional inexpensive materials, which are better insulators, and which reduce the cost over what would be necessary if the thickness of the common building materials was increased to give the same degree of insulation. In all cases, the commonly-accepted structural materials should be used to give the building strength, and the insulation should be used as additional material. That is, the insulation should not be substituted for structural material.

It has been noted that a dead air space is a very good insulator. The better insulators owe their value to the fact that they are porous, and thus contain a large number of dead air cells. Most of the insulators on the market have approximately the same proportion of dead air cells. Therefore, their insulating values, for the same thickness of material, are not essentially different. It should be emphasized, however, that the commercial insulating materials are made in different thicknesses. More confusion has arisen from this practice than from any other. The insulating values should be compared on the basis of the same thickness, and not on the thickness as made. For really

effective insulation, a thickness of at least  $1\frac{1}{2}$  inches should be used in addition to the regular structural materials.

In comparing insulators, even when used in the same thickness, some consideration must be given to the structure of the walls in which they are to be used. When the insulator is installed, only part of the original heat loss from the wall can be saved, and the percentage thus saved depends on the original heat loss. That is, a larger percentage saving can be effected by insulating a poor wall than by insulating a good one.

A saving of about one-half of the heat loss through a given wall or ceiling can be effected by sufficient insulation. But this is not reflected as a saving of one-half in the fuel bill. The total heat loss from the average house includes about 27 per cent through the walls, 30 per cent through doors and windows, and 27 per cent by air leakage through cracks around windows and doors. Accordingly, for the average two-story house, from ten to fifteen per cent is a conservative estimate for the possible saving in fuel accomplished by insulating the walls alone. An additional ten per cent may be obtained by insulating the second story ceilings. This makes a total saving of from twenty to twenty-five per cent by thorough insulation, equivalent to  $1\frac{1}{2}$  inches of rock wool. An actual saving of about thirty per cent was obtained in the fuel bill by thoroughly insulating the Warm-Air Heating Research Residence.

These savings are possible, however, only if strict attention is given to obtaining correct construction. Where insulation in board or blanket form is used in frame walls, the spaces between the studding should be made air tight, both at the top and the bottom, and preferably stopped at the center also. Circulation of air in the studding space, and between ceiling joists, may easily reduce the effectiveness of insulation by fifty per cent. By completely filling the walls with insulation, the air circulation is effectively stopped, but even in this case good construction is essential.

Up to this point, the desirability for good construction has been emphasized only in connection with its bearing on the question of fuel economy. While this consideration is doubtless important, the direct effect of house construction on comfort is even more important, for fuel economy is meaningless unless it is also accompanied by a high degree of comfort.

The modern theory of comfort regards the human body as a heat engine, and recognizes the fact that all bodily processes and activities ultimately result in heat production. This heat must be removed at the same rate at which it is generated, or else the normal functions of



the body will be interfered with, and some degree of discomfort will result. If the environment is not favorable to permit this loss of heat, the body attempts to compensate for it by making adjustments tending to accelerate or retard the loss. As long as the individual is unconscious of such adjustments, a state of comfort exists, and discomfort begins as soon as the operation of the mechanism of adjustment becomes consciously apparent. The function of a heating plant is, therefore, not to warm the body, but to produce an environment in which the body can lose the correct amount of heat without conscious bodily adjustments.

Heat is lost from the body by convection, which depends on the temperature of the air, and by radiation, which depends on the temperature of the surrounding walls. If the walls are cold, a correspondingly high air temperature must be maintained in order to produce comfort. Measurements on exposed frame walls indicate that the inside surface temperature may be as low as 52 deg. F. with zero outdoors. Normally, comfort would exist with both the walls and air at 72 deg. However, if the body is exposed to three cold walls at 52 deg. F., the air temperature must be raised to 78 deg. in order to produce the same degree of comfort. If these walls were properly insulated, the inside surface temperature would be 68 deg., and a room air temperature of 73 deg. would be sufficient to give the same comfort as that existing with both air and walls at 72 deg.

A common source of discomfort is the presence of cold glass surfaces. With ordinary glass windows, the temperature of the inside surface of the glass is approximately 18 deg. F. with zero outdoors. The addition of storm sash would increase this temperature to 42 deg., with a corresponding increase in comfort.

In a given environment, a glass thermometer loses heat at a rate relatively less than that for the human body, and is, therefore, less influenced by the presence of cold walls. Hence, a reading of 72 deg., which would normally indicate comfort, may be very misleading as an index of comfort if a considerable amount of cold walls and glass is present. Such a reading may be misleading in another respect, inasmuch as thermometers are usually placed about five feet from the floor. In very cold weather it is not unusual to find temperatures near the floor as much as ten degrees lower than those at the five foot level. In this case, the thermometer at the five foot level may indicate a temperature sufficiently high for comfort, while the greater part of the body may be surrounded by air at a temperature too low for comfort. This is particularly true for individuals seated.

The amount of moisture in the air, or the relative humidity, is a factor having some influence on comfort. Relative humidity below twenty per cent is distinctly uncomfortable, but thirty per cent is sufficient for reasonable comfort. If greater than thirty per cent is present, an excessive amount of water or frost will appear on window panes. Tightly-fitting storm sash will eliminate this. Furthermore, with more than thirty per cent relative humidity, water vapor may condense inside of insulated walls. This may be prevented by installing heavy double-glazed asphalt paper between the insulation and the plaster.

Hence, it is apparent that problems relating to both fuel economy and comfort, particularly if high relative humidities are to be maintained, cannot be separated from considerations of proper house construction; and, within reasonable limits, additional expense incurred in order to obtain good construction may be regarded as an economically sound investment.

#### IV. HOME INSULATION

SEICHI KONZO\*

No more effective way exists of reducing fuel consumption than by applying storm windows, storm doors, and adequate insulation to the ceiling and sidewalls of a house. These items can be considered as equivalent to an "overcoat" for the house.

The first "must" requirement for adequately protecting the house is the use of storm doors. In an average house, about four to five per cent of the heat lost from the house is through and around the door. Hence, if by applying a tightly-fitting storm door, we can cut this loss about one-half, we shall effect reductions of about two to three per cent. This sum may not seem significant, but when we consider the returns on the investment and the ease of installing a storm door, it seems a most logical thing to do.

If you are renting your house, and the owner cannot afford a storm door, you should consider the simple expedient of applying weather stripping to the door, particularly if it is warped and considerable air whistles through the cracks. Felt stripping sufficient in length to weatherstrip a door may be purchased at a hardware store for about ten or fifteen cents. These strips can be readily tacked on to the door frame so that when the door is closed a fairly tight seal is made. This type of weatherstripping is not as effective as a tightly-fitting storm door, but is better than none at all.

The second "must" requirement is the application of storm sash to the windows. Tests made in the Warm-Air Heating Research Residence at the University of Illinois have shown that when tightly-fitting storm sash was applied to all the windows in a house, a saving in fuel consumption of about twenty per cent was obtained. The storm sash should be tightly fitted and should be drawn up tightly when closed. It should be realized that a properly-installed storm sash not only reduces the heat transmitted through the glass, but also reduces the air leakage around the windows. With tightly-fitting storm sash it is not necessary to have separate weather stripping attached to the inside windows. If necessary, felt stripping can be tacked on the storm sash to seal any cracks between the storm sash and the window frame. If, on account of the expense involved, all of the windows cannot be protected at one time, at least those windows which face the north and west should be protected. Other storm sash can then be added later.

Storm sash also increases comfort. If you place a thermometer on the window sill you will find that the temperature of the air rolling off the cold window surfaces will be considerably lower than the temperature of the air in the middle of the room. When storm sash is applied to the window, the quantity of cold air that rolls down the window is reduced and the temperature is increased. This cold air that rolls off the window settles to the floor. Tests have indicated that by the use of storm sash the air temperature at the floor level, or the crawling level for a youngster, is increased two or three degrees in cold weather. In addition to raising the temperature at the floor level, the use of storm sash raises the temperature of the glass surface which faces the occupant, and thereby reduces the radiation of heat from the human body to the cold surface. Probably most of you have noticed that windows protected with storm sash do not condense moisture, or "fog," as readily as unprotected windows. This is further evidence of the fact that the inside glass temperature has been raised. An additional benefit that accompanies the use of storm sash will be appreciated by the homeowner. To a very large extent the soot that comes in around the ordinary window can be stopped by the double seal, so that in a sooty neighborhood it will no longer be necessary to dust off the soot that otherwise collects on the window sills. Taking all these benefits into consideration it appears that money invested in storm sash pays rich dividends.

The third "must" requirement is the use of insulation in the attic floor. We recommend that over the ceiling lath that is exposed in the attic, a layer of asphalt-treated paper be laid. This paper is technically known as a "vapor barrier," and serves to prevent moisture from leaking through the plaster and collecting on the underside of the roof covering. Some of the insulation that is available on the market comes in the form of a roll about 14 inches wide and from 1 to 4 inches thick, and is covered on one side with a "vapor barrier." This side of the roll or batt should be applied next to the lath. If a loose form of insulation is to be used, the insulation should be poured out of the bag and should cover the vapor barrier to a uniform depth. In any case, whether the roll form or the loose form of insulation is applied, we recommend that at least a two-inch thickness be used, and preferably a four-inch thickness. In the case of an unfinished attic floor it is also possible to nail insulating boards over the attic joists. These insulating boards are usually available in thickness of from  $\frac{1}{2}$  to 1 inch, and can be readily handled by any homeowner. If the attic is partly floored it may be necessary to lift up the flooring to apply the

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insulation, or to have the insulation contractors blow the material into place. In some cases in which the homeowner contemplates finishing the attic space into extra rooms, it may be advisable to apply the batt or board types of insulation to the underside of the roof rafters.

A few words about the different types of insulation may be pertinent at this point. The most common form of insulation in use is called mineral wool, and consists of thin strands of hair-like material that has been blown from molten rock, glass, or slag. Air is trapped between the closely-meshed fibers, and heat is transmitted very slowly through the porous material. The board type of insulation is also in common use, and usually consists of some cellular material that has been compressed into a rigid board. In this type of insulation, also, the air is trapped between the fibrous material. It is not good practice to use shredded newspapers, sawdust, or other types of insulating material that will absorb moisture, that will attract insects or mice, that will be highly inflammable, or that will collapse with age.

In general, the differences in effectiveness between the various types of mineral wool that are offered for sale are rather small. It is highly important that the insulation be applied uniformly over the entire area. In addition to its proven merit of reducing the heat loss, adequate insulation will make the ceiling surfaces warmer, and will also tend to cut down on the soiling of the ceiling surfaces. In the average house, the use of two inches of ceiling insulation will result in a reduction of fuel of about ten to twelve per cent.

The fourth requirement, which may be relatively more expensive than the three which have been mentioned, is the insulation of the sidewalls of the house. The only practical method of insulating the walls of an existing house is to blow the loose type of wool insulation into the studding space by means of a blowing machine. This work should be done by competent workmen. In the average house, the use of insulation in the sidewalls will reduce fuel consumption by about 15 to 17 per cent.

If windows are loose and wind whistles through the cracks, weatherstripping placed along the edge of the sash will serve to reduce the air leakage. If a strip of cellulose tape is applied to the crack between the upper and lower sashes of the window, most of the air leakage at that point can be eliminated. Weatherstripping of the inside windows will not be necessary if tightly-fitting storm sash are applied on the outside.

In some old houses the woodwork around the window and door frames has shrunk to such an extent that large cracks are apparent. Homeowners should be able to borrow a calking gun and purchase calking material from building supply houses. These cracks, which allow wind and rain to penetrate the outer surface of a house, can be readily sealed with calking material.

Many homeowners do not realize that the heat escaping from the furnace and smokepipe into the basement serves not only to keep the basement warm, but also serves indirectly to heat the floors of the first-story rooms. Hence, if basement window lights are broken, or large quantities of outdoor air leak into the basement through cracks around the windows, doors, and the foundation sill, much valuable heat will be lost. It is good practice to make the basement reasonably tight. Some homes are built without a basement, so that the floors are exposed either to an unheated space or to the outdoors. If possible, the air leakage into the unheated space should be reduced. If the basement space is entirely open to the outdoor air, it may prove advisable to insulate the under part of the floor with a one-inch thickness of board insulation nailed to the floor joists, or to apply the batt form of insulation between the floor joists. A cold space below the living rooms of a house creates cold floor surfaces, and a cold floor surface is not conducive to comfort no matter what the air temperature in the room may be.

We recommend that each homeowner make a critical inspection of his own home starting from the basement and going up to the attic. Inspect basement windows, doors, frames, ventilation opening; inspect windows, doors, frames, walls, and ceilings on the upper stories; inspect the attic space. Look for every possible source of air and heat leakage, and take steps to plug the openings.

By completely protecting the house by means of the four steps mentioned, reductions in fuel consumption of the following amounts in the average home can be expected:

Storm door—2 to 3 per cent.

Storm windows—20 per cent.

Ceiling insulation—10 to 12 per cent.











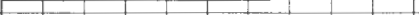


Sidewall insulation—15 to 17 per cent.

or a total of approximately 50 per cent. Actual tests conducted in the Warm-Air Heating Research Residence at the University of Illinois showed that the total coal consumption was reduced about one-half when all of the protective measures were applied.

As incidental, but nevertheless significant benefits, it has been



shown that soot leaking through windows and doors was reduced, walls and ceiling surfaces were warmer, floors were warmer, outside noises were eliminated, and a great deal of the load on the furnace was removed. If the heat loss of a house is materially reduced, it is obvious that the furnace will not have to be forced as much in order to heat the house, and that, as a result, the life of the furnace should be prolonged. If, as a result of reducing the heat load on the furnace, it is possible to avoid prolonged periods of high intensity firing, to that extent also will the fire hazards resulting from overheated smokepipes and chimneys be reduced.

Case	Insulation		Weather Strip	Storm Sash	Calculated Hourly Heat Loss in Per Cent of Maximum Rate						Reduction, %
	Wall	Ceiling			0	20	40	60	80	100	
a	None	None	None	None							0
b	1-in.	None	None	None							12.8
c	2-in.	None	None	None							17.4
d	3-in.	None	None	None							19.7
e	3 5/8-in.	None	None	None							20.3
f	None	1-in.	None	None							11.3
g	None	2-in.	None	None							13.3
h	None	3-in.	None	None							14.1
i	None	3 5/8-in.	None	None							14.5
j	3 5/8-in.	3 5/8-in.	None	None							34.8
k	None	None	Yes	None							9.8
l	None	None	None	Yes							31.3
m	3 5/8-in.	3 5/8-in.	None	Yes							66.1

CALCULATED HEAT LOSSES OF TYPICAL RESIDENCE

## V. EFFICIENT WARM-AIR HEATING

SEICHI KONZO\*

The War Production Board has virtually stopped the manufacture of warm-air furnaces. Furthermore, although repairs and replacements can be made, a new furnace cannot be installed unless it can be clearly proved that the old furnace is damaged beyond repair. Let us look at the implications of this ruling, and see how it may affect your heating plant.

It is quite evident that your present heating plant will have to serve for the duration. Every effort should be made to improve its efficiency and to prolong its service. A few weeks still remain during which some of the necessary repair and cleaning work can be done readily.

Probably no single source of complaint is so aggravating as the lack of chimney draft to carry away the smoke and gases formed when coal is burned. In a great many cases the chimney is too low, too small, or so poorly built that, even after much patching and repairing is done, the chimney still does not draw well. Nevertheless, that should not prevent one from trying several corrective measures. We recommend that the following steps be followed:

First, the smokepipe from the furnace to the chimney should be taken down and thoroughly cleaned. If the smokepipe is corroded and eaten through so that numerous pinpoints show on the outside, it should be replaced with a new smokepipe. A worn out smokepipe is a definite fire hazard. The fire records for the country show that one of the largest sources of fires in the home is defective smokepipe and chimney construction. It is false economy to attempt to save a few pounds of metal required for the smokepipe, if at the same time the safety of the house is endangered.

Second, the cleanout door at the base of the chimney should be opened and the accumulation of soot and loose ash removed. If you will place a small hand mirror through this opening you should be able to see up the chimney, provided it does not have a bend, and provided that it is not obstructed by loose tile or brick. Any obstruction in the chimney should be removed. After the soot has been removed through the cleanout door of the chimney, the door should be tightly closed, so that no air leaks into the chimney.

Third, the soot which has accumulated in the furnace should be removed. Any soot which covers the inside of the furnace not only

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d	3-in.	None	None	None							19.7
e	3½-in.	None	None	None							20.3
f	None	1-in.	None	None							11.3
g	None	2-in.	None	None							13.3
h	None	3-in.	None	None							14.1
i	None	3½-in.	None	None							14.5
j	3½-in.	3½-in.	None	None							34.8
k	None	None	Yes	None							9.6
l	None	None	None	Yes							31.3
m	3½-in.	3½-in.	None	Yes							66.1

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m	3 5/8-in.	3 5/8-in.	None	Yes							66.1

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reduces the draft, but also reduces the efficiency of the furnace, in some cases by as much as 2 to 5 per cent. It is particularly important in the case of a steel furnace to remove the soot that has collected in the radiator of the furnace, which is located toward the rear. Most steel furnaces have convenient cleanout doors through which the soot can be removed easily. Most of the cast iron furnaces have cleanout doors located above the firing door. A large proportion of the soot can be scraped out with a long-handled hoe and a brush, although, for a thorough cleaning, a furnace vacuum cleaner, such as every furnace contractor owns, will be required. We particularly urge you to remove all soot at the end of the heating season, since a soggy mass of soot, which contains sulfuric acid, will eat through the metal in the smokepipe and furnace during the damp summer months.

Fourth, after the smokepipe has been replaced, all the cracks and holes in the smokepipe and chimney, that will allow basement air to leak into the smokepipe, should be closed. Every opening in the smokepipe will tend to reduce the draft that is available at the furnace. The smokepipe should be installed rigidly so that it will not fall down in the event of a puff or explosion in the furnace. Coal gases are poison gases, and should be handled with respect.

A second source of complaint that is frequently encountered is that the furnace has to be fired very heavily in order that some rooms in the house may be heated. The usual complaint is that the casing or jacket of the furnace gets hot, the basement is very warm, the smokepipe is almost red, and the air coming from the registers is hot but insufficient in quantity. We might aptly term this condition as "furnace asthma." Due to the lack of warm air or return air pipe capacity, the furnace is literally strangled, and a feverish condition develops. A heating plant which shows these pronounced symptoms of strangulation needs circulating air and plenty of it. If circulating air is not furnished in adequate quantities, fuel will be wasted, and the life of the furnace will be shortened. It should be realized that in order to obtain heated air from the registers it is necessary to deliver cooler air to the furnace. In some installations, the furnace may be adequate in size to heat the house, but a bottleneck exists in the warm-air duct system so that the heated air cannot flow freely upwards. In a majority of improperly-installed heating plants, however, the bottleneck exists in the return duct system. Either the return air grilles are blocked, the return air ducts are too small, or the return duct system is too long and has too many sharp-angled bends. The return air ducts should be short, large in diameter, and streamlined, if the air is to flow

freely back to the furnace. Tests made in the Warm-Air Heating Research Residence at the University of Illinois have indicated that a long, non-streamlined duct may be only 44 per cent as effective as a shorter streamlined duct of the same diameter. As a very rough rule, the areas of the return air ducts should be at least the same as the areas of the warm-air pipes leading from the furnace bonnet.

One of the simplest methods of testing whether the return air duct system is adequate or not is to disconnect temporarily a return air duct in the basement so that basement air flows into the furnace. If the heating plant has been lacking in air supply the temporary opening will serve to relieve the constriction and will allow a greater air movement through the system. The immediate effect should be observed in a marked decrease in air temperature at the register and an increase in the air volume at the register face. After this simple test has been performed, the return duct should be reconnected. If the test indicates that additional return air capacity is needed, provision should be made to have it installed.

Occasionally we find that the existing return air ducts are not functioning properly, due to the fact that the duct is being heated either from a near-by hot smokepipe, or a hot casing, or from heat reflected from the furnace to the bottom connection of the return duct. If the return duct is in close proximity to a hot surface, a metal shield placed between the duct and the surface will act as an insulating shield. If the connection of the return air duct to the furnace casing extends higher than the level of the furnace grates, it may be advisable to place a shield inside the casing to cut down the radiation from the furnace to the bottom and sides of the return duct. It should be apparent from this discussion that the return air duct should not be carried over the top of the furnace, for the duct will be heated from the furnace bonnet and will be largely ineffective. In other words, if a return air duct is heated at any point from some external source, the suction effect of the duct will be reduced.

In some of the older installations, certain rooms on the second story may fail to heat because of the inadequate warm-air duct that was installed. In most cases of this sort the construction of the building does not permit the addition of another warm-air duct to the second story. We recommend in these cases that every attempt be made to reduce the heat losses from these rooms. This can be done by the use of storm sash on the windows, calking of window frames, and the use of insulation in the attic floor.

Experience has indicated that a warm-air system that is properly

installed and handled with reasonable care will have an operating life of twenty years or more. An improperly installed system that has been overfired may have a life only a fraction as long. The research staff at the University has prepared a technical publication which is being distributed by the National Warm-Air Heating and Air Conditioning Association and which should be in the hands of the heating contractor. Your heating contractor should use this "Gravity Manual" when checking over your installation. With its use he will be able to determine whether the warm-air and return air pipes are sufficient in size and number. In this connection we would like to recommend that only competent and experienced heating contractors be consulted.

As a brief summary of the things a homeowner can do, or have done, on a warm-air heating system, the following items may be of interest:

(1) Remove rugs or low furniture that block the openings of a return air grille, and prevent the free flow of air back to the furnace.

(2) All of the joints in the return air ducts, the furnace casing, the furnace bonnet, and the warm-air ducts should be sealed with strips of asbestos paper. A strip of asbestos paper, about 2 inches wide, should be dipped in a thin liquid paste made from rice flour and then placed over the joints. It is not necessary nor advisable to cover the sheet metal away from the joints. These seals will effectively stop any dust from leaking into the furnace casing. Not one plant out of ten is as tightly sealed as it can and should be.

(3) Install storm sash, storm doors, and insulation. It is not difficult at all to heat a well-protected house, but even the best heating system in the world will have difficulty in heating a tent.

(4) Protect the top of the furnace casing, which is called the bonnet, with a layer of sand, or some material that is not combustible.

(5) Every three or four years the joints in the castings of a cast-iron furnace should be reset with liberal applications of furnace cement by your heating contractor.

(6) The air filters in a forced warm-air heating system remove dust and lint from the circulating air. The filters should be replaced or cleaned each season. If the filters become clogged with dust, the flow of air to the furnace will be reduced, and fuel consumption will tend to increase.

(7) The bearings on damper motors, stoker motors, oil burner motors, fan motors, and fans should be oiled once each season.

(8) Any scale that has collected in water pans should be removed.

and the water should be flushed out of the pans at the close of the heating season.

(9) In a coal-fired furnace the ash-pit door should fit tightly, and the dampers which control the air supply to the fuel should operate smoothly.

These items are some of the things you or your service man can perform. It is good practice to have this annual servicing done each spring after the heating plant has been shut down. It may not be too late now to recondition your heating plant.

## VI. EFFICIENT STEAM OR HOT-WATER HEATING

W. S. HARRIS\*

Very frequently the only attention the heating system gets is to see that it is supplied with fuel in cold weather and that the ash is occasionally removed from the ash pit. In those homes where a fully automatic oil- or gas-burning system is used, it frequently gets no attention at all except in the event of a complete failure of some sort. A house-heating plant is a piece of mechanical equipment which represents a sizeable capital expenditure, and, as is the case with all mechanical equipment, it can only give the maximum of efficient service if properly cared for. In past years, the question of an annual heating plant inspection was purely one of economics. If one wanted to secure the most out of each heating dollar one had it done, but because heating systems continue to give reasonably good operation without the annual checkup, most of us just neglected to have a checkup made and, as a consequence, we often burned more fuel than necessary, or even shortened the life of the heating equipment. This year it is not a question of economics alone. Because of the extremely heavy demand by our armed forces and our war industries upon the supply of coal and oil, as well as upon our transportation facilities, it is certain that some form of fuel rationing will be required here. Therefore, it is the duty of all of us to do all we can to conserve fuel and all other critical materials so vital to our war effort. For each of us to make sure that our heating system is conditioned so as to operate at peak efficiency is just one of the ways in which we can do our part.

It is convenient to classify heating systems according to the fuel burned. By far the most popular fuel used in this section is coal, so let us consider the coal-fired system first. At the end of last heating season the grates should have been cleaned of all ash and unburned coal and all refuse removed from the ash pit. If you did this you helped to lengthen the life of the grates and other castings by minimizing the amount of rusting occurring during the summer months. If you have a stoker the fire pot and stoker should have been emptied of clinker, ash, and coal, and oil applied to the unprotected metal surfaces of the feed screw, feed tube and inside of hopper to prevent rusting. Of course, it is too late to do anything about it this year if these things were not done in the spring, but they are worth keeping in mind as a job to be sure to include in next spring's house cleaning program.

\*Special Research Associate in Mechanical Engineering, University of Illinois.

However, there are many items which should be included in the annual inspection of a heating plant which it is not too late to take care of now.

For maximum efficiency heating surfaces should be clean. One thirty-second inch of soot or fly ash on the heating surfaces can easily cause an increase in the seasonal fuel consumption of five per cent or more. Therefore, at least once a year and oftener when necessary, the heating surface should be cleaned of these deposits by means of a stiff brush or by a vacuum cleaner especially designed for the purpose.

Air leaks around the fire door, ash door, and the base, or between the sections, all waste fuel. Also, they may permit objectionable odors from the products of combustion to enter the house. So go over your heating plant after cleaning out the soot and stop up these leaks. There are several varieties of asbestos cement on the market which are made especially to seal leaks of this kind.

While you are inspecting the boiler for leaks, open the drain valve at the bottom of the boiler and drain off enough water to remove the sludge and corrosion which settles to the bottom when the system is not in use; then be sure to add sufficient water to refill the system to the proper level.

Check the condition of the insulation on your boiler and basement heating pipes, and repair or patch where required. Inadequate insulation on the boiler or piping allows much of the heat which should be used to heat the living quarters of your house to escape into the basement instead. It is true that some of the heat so released in the basement eventually finds its way into the first-story rooms and, therefore, is not wholly lost. However, this is not an efficient way in which to distribute heat. Adequate insulation covering your boiler and piping will save you fuel, and normally will result in more satisfactory heating. This is especially true in the case of steam systems.

If you use a stoker, be sure it has an adequate supply of oil in the transmission and the motor bearings before you place it in operation for the winter. It is also wise to have your stoker service man check it over to see that everything is in proper running order and adjustment. If you make sure the "hold fire" control is set to burn a minimum amount of coal it will save you fuel and also help prevent overheating in mild weather.

For a nominal charge, most dealers will make an annual inspection of oil burners during the summer months in which they will clean the oil strainers, filters and nozzle, make any necessary adjustments in the rate of oil and air supplied, check the ignition, oil all bearings, and



clean the burner generally. They also will check the condition of the combustion chamber and suggest repairs when they are required. Taking advantage of a service of this kind often saves a more expensive service call during the winter to repair some breakdown which never would have occurred if the plant had been placed in proper running order before winter began. If the burner is out of adjustment so that the air and oil for combustion are not properly mixed and in the correct proportions, you may waste as much as twenty per cent of the fuel burned because of improper combustion. The symptoms of improper combustion are (1) excessively high temperature of the flue gas leaving the boiler, (2) smoke in the flue gas, (3) excessive carbon deposits on the heating surface or (4) excessive oil consumption. If you note any of these symptoms, your burner may need adjusting. But do not try to do it yourself. The chances are that you may only make it worse. Call in your service man. He has the training and the necessary instruments required to make sure your burner is adjusted to operate at peak efficiency.

Thus far we have discussed only the conditioning of the basement unit of the heating system for efficient winter operation. However, we must not overlook the radiators themselves, for no matter how efficient the operation of the boiler and distributing system may be, we cannot obtain satisfactory and economical heat unless we have adequate radiation, properly installed. In getting your home heating system ready for the most efficient service, be sure that furniture or drapes do not obstruct the free movement of room air over the radiators. It is from this circulation of air over the radiator, by processes we call convection and conduction, that a large proportion of heat is transferred from the radiator to the air in the room. The practice of using a radiator as a magazine rack or a convenient place to lay the bath towel in no way helps that radiator do its intended job of keeping the room warm. Such unconventional use of a radiator will not ordinarily result in increased fuel consumption unless the radiator happens to be in one of those hard-to-heat rooms, and the other rooms are somewhat overheated in order to keep the hard-to-heat room comfortable. If this should be the condition in your home, you may be able to correct or at least improve the heating problem in that room by merely removing all objects on or around the radiator so that it will have a better opportunity to transfer its heat to the room air.

Often radiators are equipped with enclosures or shields. Usually this is done from the decorator's point of view. Nevertheless, if they are properly designed they will improve the performance of a radiator. A properly designed enclosure or shield should offer a minimum

resistance to the flow of air over the radiator. It should also protect the wall behind the radiator from direct radiation.

Recent tests conducted at the University of Illinois on recessed radiators have indicated that a reflective surface located against the wall behind the radiator will reduce the amount of heat lost to the outdoors through that portion of the wall by as much as thirty-five per cent. These tests indicated a 6.5 per cent fuel saving resulting from the use of reflective insulation behind the radiators. For these tests a bright metal foil was used as the reflecting surface. However, if this cannot be obtained, painting the wall behind the radiator with aluminum bronze paint will reduce the amount of heat lost to the outdoors through this part of the wall.

Painting a radiator with oil paint regardless of color has no material effect on the heat output. Metallic bronze paint should not be used as a radiator paint, as tests have shown that its use on the radiators will reduce their output by approximately nine or ten per cent.

Steam heating systems are only as good as the air vents on the radiators will permit them to be. Steam cannot enter the radiator until the air has been expelled, and unless the vents allow the rapid escape of air from the piping and radiators, fuel is wasted, and at the same time certain rooms in the house may be underheated. Therefore, it is only a matter of economy to be sure that all air vents are working properly and defective vents are replaced.

In a hot-water heating system the radiators are supposed to be full of water at all times. In the course of time certain dissolved air and gases are driven from the water in the heating system and collect at the top of various radiators in the house. If this air is not removed from the radiators by opening the vents occasionally, it may prevent the normal circulation of water through the unit. In the case of hot-water convectors which are now in common usage, venting is more critical, as a very small quantity of air in the unit may completely stop the circulation of water.

Some of the suggestions I have just made, as well as some others which we do not have time to discuss today, relative to methods of improving the performance of radiators, are to be found in the University of Illinois Engineering Experiment Station Bulletin Number 223 entitled "Investigation of Various Factors Affecting the Heating of Rooms with Direct Steam Radiators." This Bulletin can be obtained from the Engineering Experiment Station and, while it is of a technical nature, it can be understood by the average non-technical reader interested in learning how to obtain the best possible performance from a steam or hot-water heating system.

## VII. MORE FUEL-SAVING HINTS

W. S. HARRIS\*

If we are to use less fuel this year to heat our homes, we must (1) reduce the heat loss of the house, (2) decrease the average difference between the indoor and outdoor temperatures during the heating season, (3) heat less space, or (4) operate our heating system in a more efficient manner.

Because air cannot be seen, many people do not realize how much warm air goes up a fire-place chimney if the damper is left open. All warm air removed from the house is replaced by cold air from outdoors which enters the house through cracks around windows and doors and, even to a certain extent, through the walls themselves. To keep the room temperature from dropping, this cold air must all be heated to room temperature which, of course, requires additional fuel. So be sure the damper in the fire-place chimney is tightly closed when the fire-place is not in use. This helps a lot to reduce fuel consumption by reducing the amount of warm air escaping from the house.

Another obvious way to reduce fuel consumption is that suggested in the oil-rationing plan, namely, dressing more warmly and keeping houses cooler. In climates such as we have throughout central Illinois, the fuel consumption will be reduced approximately 3 per cent for every degree we lower the house temperature below 70 deg. F. However, it is not possible to lower the house temperature much below 70 degrees and maintain comfortable conditions. If the heat loss of a house is decreased 3 per cent for every degree the house temperature is lowered below 70 degrees, it is obvious that there will be approximately a 3-per-cent increase in the heat loss for every degree the house temperature is raised above 70 degrees. In other words, while underheating may bring discomfort to the occupants of the house, on the other hand, in the interest of fuel economy, we should be careful not to over-heat our homes.

There are other ways of saving fuel that can sometimes be applied which do not require the lowering of the temperature in the whole house. When possible, these methods should be employed in preference to maintaining the whole house at an uncomfortably low temperature. Unused rooms should not be heated. If you have a room in your home which does not have to be occupied this winter, turn off the heat in that room. Make sure that all plumbing or water pipes in the room are drained or otherwise protected against possible freezing. In closing unheated rooms off from the rest of the house, one should seal the

cracks around the doors, particularly the big one at the bottom. If these cracks are not stopped by a felt strip or some similar material, they may be a source of cold, objectionable drafts in the heated portion of the house, and they will tend to decrease the amount of fuel saved by not heating the unused room. The amount of space in the unheated room as compared to the total space in the rest of the house will give a rough indication of the amount of fuel which can be saved by not heating an unused room this winter.

Many of us have been heating our garages in the past. This is not essential, and requires considerable fuel, and should, therefore, be discontinued, at least, for the duration of the war. Again, if the garage has been heated in the past, but is to be unheated this year, precaution must be taken to protect any exposed water pipes from possible freezing.

Sun-rooms present a difficult heating problem. Due to the large window area and the number of cracks around windows and doors in these rooms, the heat loss is very high. Consequently, many people who are now heating sun-rooms find that they are not using them much during the winter because they are not comfortable much of the time. In such cases, it would be more economical to close the room off from the rest of the house and discontinue heating it this winter. If sun-rooms must be used, every precaution must be taken to reduce the heat loss from them. Storm windows and doors are certainly recommended for sun-rooms. They reduce both the heat lost through the glass itself and the amount of cold air entering the room through the cracks around the windows and doors. This not only reduces the load on the heating plant but also minimizes one of the chief causes of cold floors and drafts.

It is not necessary to have the house heated to 72 deg. F. at all times, and tests made both in the Warm-Air Heating Research Residence and the I-B-R Research Home here at the University of Illinois indicate that, on thermostatically controlled systems, a possible fuel saving of from 7 to 10 per cent may be obtained by reducing the house temperature 6 to 10 degrees from about 10:00 p.m. to 5:30 a.m.

It is useless to try to heat a room with open windows, so, if bedroom windows are opened at night, the heat in that room should be turned off and the door between the bed-room and the rest of the house should be kept closed during the time that the windows are open. It will also help to place a rug against the crack under the door to prevent the cold air in the bed-room from leaking into the rest of the house. If these precautions are not observed when bedroom windows are open, a severe and unnecessary tax is placed upon

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the heating system during the night and early morning, and fuel is wasted.

Often homes are unsatisfactorily heated because of improper location of the thermostat controlling the operation of the burners or drafts. The thermostat can only attempt to keep a uniform air temperature in its own immediate vicinity. Therefore, it is essential that it be located where it will not be affected by drafts or some unusual heating condition. Thermostats should never be located on outside walls and care should be taken to see that they are not located on a wall adjacent to heating pipes or hot chimneys. When the temperature of the air near the floor is much lower than that five feet above the floor or near the ceiling, a more comfortable condition is often obtained by locating the thermostat about 30 to 36 inches above the floor instead of at the usual five-foot level. Excessive fuel consumption is sometimes caused by the thermostat being located in a room which is hard to heat because the radiators or registers in that room are either too small or improperly installed. If this should be the case, the condition should be corrected either by increasing the size of the radiator or register, or correcting the defect in the installation, for when the room in which the thermostat is located is cooler than the other rooms in the house, the result is often the overheating of all the other rooms.

Today it is common practice to install an automatic draft regulator on all oil-burner installations. The purpose of the automatic draft regulator is to maintain constant draft in the furnace or boiler regardless of any draft fluctuation which may occur in the chimney due to temperature changes or wind effects. By maintaining constant draft, it is possible to maintain a higher average combustion efficiency than could be obtained without the use of the regulator. It is estimated that their use in an oil-burner installation sometimes results in as much as a 10 to 15 per cent reduction in the amount of fuel burned per season. If you are using oil, and your system is not equipped with a regulator, it will be to your advantage to have one installed.

If you have a hand-fired coal plant, as most of us do, then be sure that you know how to fire so as to obtain truly efficient combustion. Proper firing methods were discussed in one of the earlier talks of this series and are completely described in the University of Illinois Experiment Station Circular Number 46. In hand-fired heating systems, the combustion rate is determined largely by the available draft and the size of the ash pit damper. The opening in this damper may be large enough to provide air for burning 150 pounds of coal per hour unless the maximum draft is controlled in some way. A combus-

tion rate of from 15 to 25 pounds per hour is sufficient to heat the average home in the most severe weather. Combustion rates exceeding that actually required to supply the heat demand of the house are accompanied by hot flue gases escaping from the chimney. This represents an avoidable waste of fuel. Also, in hand-fired installations, it is very difficult to regulate the dampers so as to maintain efficient combustion at all times with widely varying draft conditions. Therefore, it is recommended, especially in multi-story houses or houses where the chimney draft is excessive, that draft regulators be installed here also as a means of reducing fuel consumption by decreasing the maximum combustion rate and increasing combustion efficiency.

Some hot-water and steam boilers are used not only to supply heat for the home, but also to supply domestic hot water. When a boiler is used in this way it is equipped with a control known as a low-limit or service aquastat whose function is to operate the burner or drafts so as to prevent the water in the boiler from ever dropping below some fixed minimum temperature sufficient to insure an adequate supply of domestic hot water for washing, cooking, and the like at all times. One should make sure that the setting of this low-limit aquastat is no higher than necessary, as the heat lost from the boiler and water storage tank increases rapidly with increasing temperature. Water at 150 deg. F. is satisfactory for most domestic uses of hot water. Recent tests indicate that when the water temperature is increased from 150 deg. to 175 deg. the convection and radiation loss from the boiler and hot water storage tank is increased by about 18 per cent. This, of course, is reflected in increased fuel consumption. If you are heating domestic hot water by means of your house-heating boiler be sure that the setting of the low-limit aquastat is not unnecessarily high.



## VIII. POSSIBLE FUEL SAVINGS\*

JULIAN R. FELLOWS†

You may be somewhat confused at this time by statements as to the percentages of the fuel consumption which can be saved by employing all methods and devices which have been suggested. It has been stated that application of all of the available heat-saving devices to a house which now has none of them may result in saving one-half of the fuel that is now being used. It has also been stated that if you are doing a very poor job of hand-firing your furnace, you may save one-half of the fuel you burn by improving your firing methods. From these two statements you might conclude that if you employ all the suggested heat-saving devices and improve your firing methods you would save 100 per cent of the fuel you now burn, and, consequently, not have to burn any at all. If you save one-half of the fuel you now burn by the application of heat-saving devices, you might then save one-half of the fuel that would still be required by improving your firing methods, but that would be only one-quarter of the fuel that was originally required before the heat-saving devices were applied. In other words, if it were possible to reduce the fuel consumption in your home 50 per cent by means of storm windows, insulation, etc., and 50 per cent of the remaining requirement by better methods of firing, the total reduction on the basis of the original requirements would be 75 per cent. There are probably very few homes where both the unnecessary heat losses and the firing methods are so bad that it would be possible to save 75 per cent of the fuel that is now being used. On the other hand, there are probably very few homes which are constructed and managed so well that fuel cannot be saved without any real sacrifice in comfort.

It is your duty as a patriotic citizen to save all the fuel you can, whether it be a large amount or a small amount. If every householder who burns soft coal would save ten per cent of the fuel he now burns by making improvements that will reduce the heat losses from his home, and another five per cent by improving the efficiency of his heating plant, it would reduce the load on our Nation's transportation system by fifteen million tons, and release three hundred thousand freight cars for the transportation of war materials.

Having taken every practicable step to reduce the heat losses from your home to an absolute minimum, and having employed every known

method of increasing the efficiency of your heating plant, the only way that you can further cooperate with your Government in this war-time emergency is to burn the fuel which may be supplied with the minimum of interference with the Nation's war efforts. In practically every community in Illinois the fuel which can be supplied with the least tax on the Nation's transportation system is Illinois soft coal. Soft coal is mined in every quarter of the State, and, if you live in Illinois, there is a mine within a comparatively short rail or truck haul of your home. Probably many of you have never burned soft coal in your home. Probably many of you have tried to burn it and have found the results to be most unsatisfactory. However, tests conducted at the University of Illinois have shown that all of the disagreeable features of the hand-fired heating plant burning soft coal can be eliminated or reduced to a minimum by employing the proper methods of firing. If your heating plant may be adapted to the use of soft coal and war-time necessity demands that you burn it, learn to fire it properly and you will be pleased with the results.

\*The matter herewith presented is merely the latter part of Professor Fellows' talk; the earlier part summarized the previous discussions, and is omitted to avoid unnecessary repetition.

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